Atmosphere and Severe Weather

Chapter 9

Energy

- **Radiation from Earth– Terrestrial Radiation**
  - Long wave Radiation – about 4 micrometers
- **Solar Radiation is at a constant level**
- When it hits the Earth's atmosphere,
  - **Some reflected back**
  - **The rest passes through the Atmosphere to be transformed into different energies.**

Energy, Heat and Temperature

- **Understanding Energy is fundamental to understanding severe weather**
- Difference between **Heat** and **Temperature is the how the energy is used**
  - **Energy**
    - **Kinetic energy -- internal energy of molecule movement**
  - **Temperature**
    - **Temperature** – the average **kinetic energy** of the molecules in a substance – ***sensible heat***
  - **Heat** – **energy that transfers from on object to another because of the difference in temperature**. ***Latent heat***

Types of Latent Heat

- **Latent Heat**
  - **Storage or release of energy**
    - **Evaporation- liquid water changes to gases, energy is released, cooling happens**
    - **Condensation- gaseous water vapor turns to liquid energy is stored, heating happens**

Heat Transfer

- **Conduction**
  - **Movement of heat energy from one molecule to another without changes to their relative positions**
- **Convection**
  - **Heat is transferred from one point to another by the predominately vertical circulation of fluid, such as water or air.**
- **Radiation**
  - **Wavelike energy that is emitted by any substance that posses heat**
- The heat transfers from a radiating heat coil through a metal pan to the water, moving the molecules in the water to a boil

Earth's Energy Balance

- **The Earth receives Solar Energy everyday**
  - This energy sustains the Earth
- When this energy hits the Earth's atmosphere
  - **Some reflected back**
  - **The rest passes through the Atmosphere to be transformed into different energies.**
  - **This is short wave Radiation**
- The energy the Earth reflects back is called **Terrestrial Radiation**
  - **Long wave Radiation**

Basic Heating & Cooling Processes in the Atmosphere

- **Radiation or Emission**
  - The process by which **electromagnetic energy is emitted from an object**
    - **The hotter the object the more radiation it emits**
- **Absorption**
  - The **assimilation of electromagnetic waves by striking an object**.
    - **Different objects have different absorption abilities**

- **Reflection**
  - The **ability of an object to repel electromagnetic waves without altering either the object or the waves**

Heating of the Atmosphere

- **Global Energy Budget**
  - **100 units of Solar Radiation hits the atmosphere**.
    - Some absorbed
    - Some reflected
    - Some radiated
  - **Total units radiated out 100 units**
  - **Albedo**
    - **The reflective value of an object**
      - The higher the **Albedo value** the more radiation the object reflects.
- The **atmosphere is heated by *Earth radiation*** rather than the sun radiation.

Basic Heating and Cooling Processes in the Atmosphere

- **Scattering**
  - The **act of deflecting or redirecting light waves** with gas molecules and particulate matter in the air.
  - Rayleigh Scattering – when the **shortest wavelengths are scattered (violet and blue)– causes the "blue sky"**
  - Sunset or Sunrise– **all the blue waves scattered as the energy passes through a longer atmosphere (larger angle) red, orange, and yellow left.**

The Atmosphere

- **Gaseous envelope that surrounds the earth**
- **Extends outward at least 6000 miles**
- More than half of the mass of the atmosphere found **below 3.8 miles**
- More than **98% lies with 16 miles of sea level**

- **Humans are creatures of the atmosphere**

Size of the Atmosphere
Composition of the Atmosphere

- **Relative Humidity**
  - The **most familiar** of humidity measures
  - The ratio that compares the **actual amount of water vapor in the air to the water vapor capacity of the air**
    - **Capacity** is the **maximum amount of water vapor that can be in the air at a given time**
    - As the **temperature increases, relative humidity decreases**
    - As the **temperature decreases, relative humidity increases**

Structure of the Atmosphere

- **Thermal layers** of the atmosphere
  - **<u>Troposphere and Tropopause</u>**
    - **Lowest level**, closest to sea level
      - **11 miles at equator to 8 miles at poles**
      - **Deepest over the tropical regions**
      - **Shallow over the poles**
      - **Varies with the passages of warm and cold air**
  - **<u>Stratosphere and Stratopause</u>**
    - **Extends from 11 miles above sea level to 30 miles above sea level**

Upper Thermal Layers

- **<u>Mesosphere and Mesospause</u>**
  - Begins 30 miles and ends 50 miles above sea level
- **<u>Thermosphere</u>**
  - Begins at 50 miles and gradually extends out

- **Exosphere**
  - Outer most portion of the atmosphere
  - Blends with interplanetary space

Atmospheric Pressures and Circulation

- **Atmospheric pressures are simply the "weight" of the overlying air**.
- The taller the column of air the greater the pressure.
  - So at **sea level, the column of air above is longer thus the air pressure is higher, and the air is denser**
  - At a **high altitude there is a smaller column of air, so the air pressure is lower and the air is less dense**.
- **The decrease in air pressure decreases with altitude but not at a constant rate.**

The Coriolis Effect or Force

- **Appearance of all things drifting sideways** as a result of the Earth's rotation.
- Why? If a rocket is shot directly at New York, by the time the rocket arrives at New York, the Earth has rotated and the rocket seems to have **"drifted"**
- **Applies to any freely moving object**.

Four Basic Points of the Coriolis Effect

- 1. **Regardless of the initial direction of motion**, any freely moving object appears to deflect to the **right** in the **Northern Hemisphere** and to the **left** in the **Southern Hemisphere**
- 2. The apparent deflection is **strongest** at the **poles** and **decreases progressively toward the equator** where there is zero
- 3. The Coriolis effect is **proportional** to the **speed** of the object, so a **fast-moving object is deflected more than a slow one**
- 4. The Coriolis effect **influences direction of movement only**… it has **no effect on speed.**

The Nature of Atmospheric Pressure

- **Atmospheric Pressure is the force exerted by the gas molecules on some area of the Earth's surface or on anybody**.

- **This pressure is exerted on every solid or liquid surface it touches**
- **It is omni-directional, exerted equally in all directions**.

Factors Influencing Atmospheric Pressure

- **Density and Pressure**
  - **Density is the mass of matter in a unit volume**
    - The density of a gas is proportional to the pressure on it and the pressure the gas exerts is proportional its density. The denser the gas, the greater the pressure it exerts.
  - **Atmosphere is held to the Earth by gravity**. So as the air moves away from the Earth, there is less gravity and less density, thus less pressure.
    - **Higher altitude, less density, less pressure**
    - **Lower altitude, higher density, higher pressure**

Buoyancy of Air

- **Atmospheric Stability**
  - **Stable air** –if a **parcel of air resists upward vertical movement**
    - Could become **unstable if a force is applied, such a topographical feature (mountain slope)**
    - **Stable air is NON-BUOYANT**
  - **Unstable air**– if it **either rises without any external force other than the buoyant force or continues to rise after such an external force has ceased to function.**
    - **Unstable air is BUOYANT**
    - **Unstable air continues to rise until it reaches temperature and density equal to itself, this is called the equilibrium level**.
  - The **intermediate condition is called Conditional Instability – between absolute stability and absolute instability**

Fronts

- **Boundary between a two unlike air masses**
- **Not two dimensional boundary at the surface, but a three dimensional zone of discontinuity**
  - **Warm, Cold, Stationary, Occluded fronts**

Warm Fronts

- Forms by **advancing warm air**
- **Slope is gentle, ascends over treating cool air , decreasing adiabatically as the air rises**
- Clouds **form slowly and not much turbulence** (**High cirrus clouds**, moving towards a **altocumulus or altostratus**
- **Broad precipitation, protracted and gentle**

Cold Fronts

- Forms by **advancing cold air**
- Is a **steeper front than a warm front** with a "**protruding nose**"
- **Moves faster than a warm front**
- **Rapid lifting, unstable air, blustering and violent weather**
- **Vertically developing clouds**
- If **unstable air, precipitation can be showery or violent**
- **Precipitation along the leading edge and immediately behind the ground-level position of the front.**
- **Classifications of Clouds**
  - **<u>Cirriform</u>** – thin and wispy and composed if ice crystals
  - **<u>Stratiform</u>** – appear as a grayish sheets that cover most or all of the sky, rarely being broken up into individual cloud unites
  - **<u>Cumuliform</u>** – massive and rounded, usually with a flat base and limited horizontal extent but often billowing upward to great heights
- **High– Found 20,000 Feet**, Small amount of water vapor and low temperature, and ice crystals
  - **<u>Cirrus, cirrocumulus, cirrostratus</u>**
- **Middle– 6500 to 20,000 feet**, composed of liquid water

- **Altocumulus, Altostratus**

- **Low– 6500 feet**, often appear as individual clouds, but often appear as a general overcast, somber skies and drizzly rain
  - **Stratus, Stratocumulus, Nimbostratus**
- **Vertical**– grows upward from low bases to **heights of 60,000** ft., very active vertical movements, usually associated with fair weather, or storm clouds
  - **Cumulus, Cumulonimbus**

Impact of Storms on the Landscape

- **Storms influence our lives everyday**
- **Storms impact the landscape**
  - **Negative effect**
    - Accelerate erosion,
    - Flood valleys,
    - Destroy buildings
    - Decimate crops
  - **Positive effect**
    - Promote diversity in vegetative cover
    - Increase the size of lakes and ponds
    - Stimulate plant growth with moisture

Localized Severe Weather

- **Thunderstorms**
  - **Defined as a violent convective storm accompanied by thunder and lightning**
  - **Found frequently found in conjunction with other kinds of storms**
  - **Triggered by unstable uplift**
  - **Formation called the cumulus stage**
  - **Mature stage – in which updrafts and downdrafts coexist as the cloud continues to enlarge** – heavy rain accompanied with hail, blustery winds, lighting, and the growth

of the anvil top

- **Dissipating stage -- with light rain ending the turbulence.**

Localized Severe Thunderstorms

- **Severe Thunderstorms can have**
  - **Wind exceeds 58 mph**
  - **Hailstones larger than ¾ of an inch**
  - **Generates a Tornado**
- **Conditions to create a sever thunderstorm are**
  - **Changes in wind shear**
  - **High water-vapor content**
  - **Updraft of air**
  - **The existence of a dry air mass above a moist air mass**
  - **Most important is the *Vertical wind shear***
  - ***The most damaging is the supercell storm***
  - **Hailstones can be a hazard from a thunderstorm**
- **Hailstones-cause more damage than casualties**

Tornadoes

- **Very small and localized**
- **Most destructive of all atmospheric disturbances**
- **Most intense vortex in nature , deep low pressure cell surrounded by a violently whirling cylinder of wind**
- **Less than a quarter of a mile in diameter but most extreme pressure gradients known** (100-millibar difference from the center to the edge.
- **Upswept water vapor condenses into a funnel cloud**
- **Advances along an irregular track that generally extends from southwest to northeast in the US**
- **Fujita tornado intensity scale for intensity**
- **Formation – develop in the warm moist unstable air associated with a mid latitude cyclone, along the squall line**
- **Develops out of mesocyclone, but only about half of all mesocyclones formed result**

in a tornado

- **More than 90 % of tornadoes happen in the US in Tornado Alley**

Tornadoes
Blizzards and Ice Storms

- **Blizzards-** Severe winter storms
  - Large amounts of falling snow
  - High Winds
  - Long lasting
  - Low visibilities
  - Extended periods of time
  - Often whiteouts because of the snow
  - Cold temperatures
  - Found across the country, extremely hazardous in the midland of the US
  - In the east, they can be called *nor'easters*
  - Extremely dangerous because of the wind chill

Blizzards and Ice Storms

- **Ice Storms**
  - Prolonged periods of freezing rain
  - Develop mostly in the north side of a stationary or warm front
  - Three conditions happen for Ice Storms to happen
    - Ample source of moisture in warm front
    - Warm air uplifted over shallow layer of cold air
    - Objects on the land surface close to freezing
  - Everything covered with ice
  - Often found in the mid-west or east

Fog

- **A Cloud on the ground**

- **Radiation fog** – results when the ground loses heat through radiation usually at night.
- **Advection fog** – develops when warm, most air moves horizontally over a cold surface, such as snow-covered ground or cold ocean current
- **Upslope fog or orographic fog**-- by adiabatic cooling when humid air climbs a topographic slope
- **Evaporation fog**– results when water vapor is added to cold air that is already near saturation.

Drought, Mountain Windstorms

- **Hazards created by wind and lack of rain**
  - **Drought**
    - Extended period of unusually low precipitation that produces a temporary shortage of water for people, other animals, and plants
    - More than 1 billion people around the world live in arid areas
      - Contribute to food shortages-causes famine
      - Water shortages
      - Power shortages
      - Decrease in industrial productivity
  - **Mountain Windstorms**
    - Strong winds, usually in the winter, which blow down the downward sides of mountains

Dust and Sand Storms, Heat Waves

- **Hazards created by wind and lack of rain**
  - **Dust and Sand Storms**
    - Strong windstorms carrying suspended dust causing low visibility for a long period of time
  - **Heat Waves**
    - Prolonged periods of extreme heat
      - Both longer and hotter than the year before
      - Happen under prolong high pressures

        - Responsible for many deaths from 1992 on

Linkages with Other Hazards

- Severe weather is linked to other hazards
    - Flooding
    - Mass movements
    - Wildfires
    - Long-term global climate change
    - Lightening

Natural Service Functions of Severe Weather

- There are some natural service functions of severe weather
    - There are long term services
        - Lightening from a thunderstorm can start a wildfire, which can revitalize a forest or prairie
        - Windstorms can help maintain the health of forests
        - Ice storms are a natural ecological cycle that increases plant and animal diversity in the forest
    - In the hydrological cycle, severe weather are a primary source of water
    - Humans can benefit from severe weather by enjoying a lightening show, watching a snowstorm, and watch a tornado chaser in a movie describe how they can be dumb being in the middle of a tornado

Minimizing Severe Weather Hazards

- **Severe weather will continue to threaten humans, because we can't "fix stupid"**
- **But if we as humans work at it, we can lessen the damage and loss of life**

Forecasting and Predicting Weather Hazards

- **There are many ways to forecast and predict the weather.**
    - **Use of the Doppler Radar** stations are used to predict severe weather
    - **Watches and Warnings** are posted for severe weather-if followed there can be less damage and loss of life
    - All of these **new prediction abilities** can always predict all the weather, humans have

to be aware of their surroundings and act accordingly

Adjustment to the Severe Weather Hazard

- **Although we can't control the climate, there are two ways we can reduce the loss of life and property**
  - **Mitigation activities**
    - Using safety-conscious engineering in building structures
    - Installing warning systems
    - Establishing hazard insurance
  - **Preparedness and Personal Adjustments**
    - Establishing community and individual plans and procedures to deal with an impending natural hazard